AGH

AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Physics and detector R&D for future projects

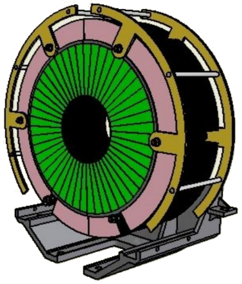
Marek Idzik

For AGH-UST and IFJ PAN

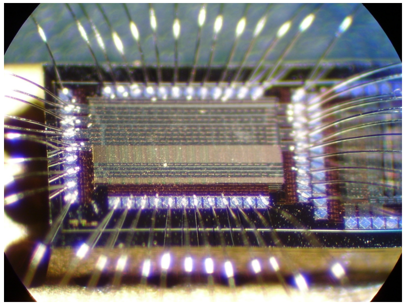
Restricted ECFA Meeting 11 May 2012 Kraków, Poland

Outline

- Physics and detector R&D for linear colliders ILC/CLIC



- Detector R&D for LHCb upgrade



Physics and detector R&D for linear colliders ILC/CLIC

- Institutions in Poland:
  - **Kraków: AGH-UST, IFJPAN, ?**
- Participants:
  - **Staff/PhD/Technical: 3/3/3**
- Main responsibilities
  - **R&D and prototyp. of LumiCal Detector**
- Main contributions and financing:
  - **Lab equip. (MNiSzW) 2010-2012 ~300kE**
  - **EUDET (FP6+MNiSzW) 2007-2011 ~350kE**
  - **MC-PAD (FP7+MNiSzW) 2009-2012 ~300kE**
  - **AIDA (FP7+MNiSzW) 2011-2014 ~200kE**
  - **??? >2014**

FCAL Collaboration

Development of very forward region of a future linear e+e- collider

Webpage - http://fcal.desy.de

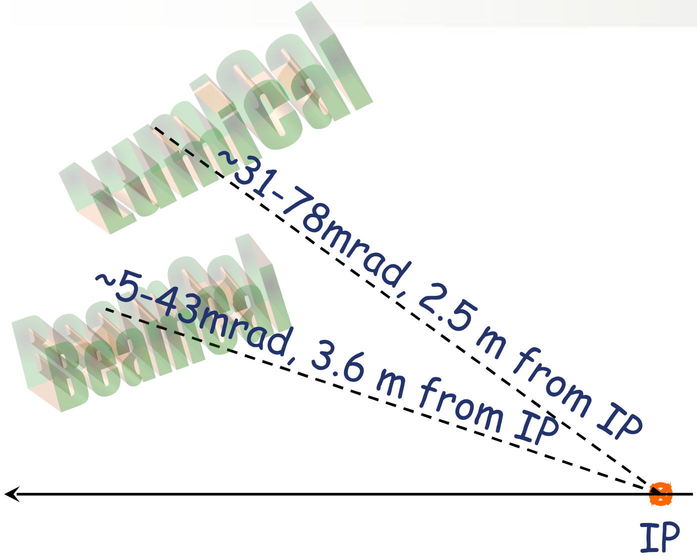
Management:

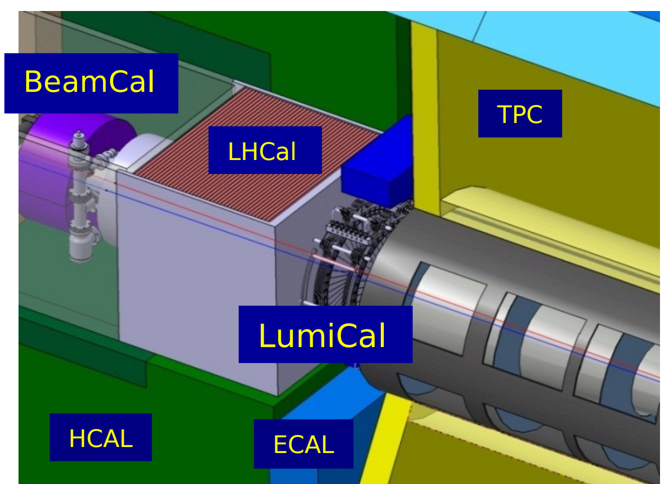
- Spokesperson: W. Lohmann (DESY)
- Deputy: H. Abramowicz (TAU)
- Technical Coordinator: M. Idzik (AGH-UST)

Institutes involved:

AGH-UST Cracow, Poland, ANL Argonne USA, CERN Geneva Switzerland, DESY Zeuthen Germany, IFIN-HH Bucharest Romania, **IFJ PAN Cracow Poland,** ISS Bucharest Romania, JINR Dubna Russia, LAL Orsay France, NCPHEP Minsk Belarus, SLAC Menlo Park USA, Stanford University Stanford USA, TAU University Tel Aviv Israel, Tohoku University Sendai Japan, UC California Santa Cruz USA, University of Colorado Boulder USA, Vinca Belgrade Serbia

Very forward instrumentation for e+e- collider





LumiCal – luminosity calorimeter

- precise luminosity measurement
- 10^{-3} at 500 GeV @ ILC, 10^{-2} at 3 TeV @ CLIC

BeamCal

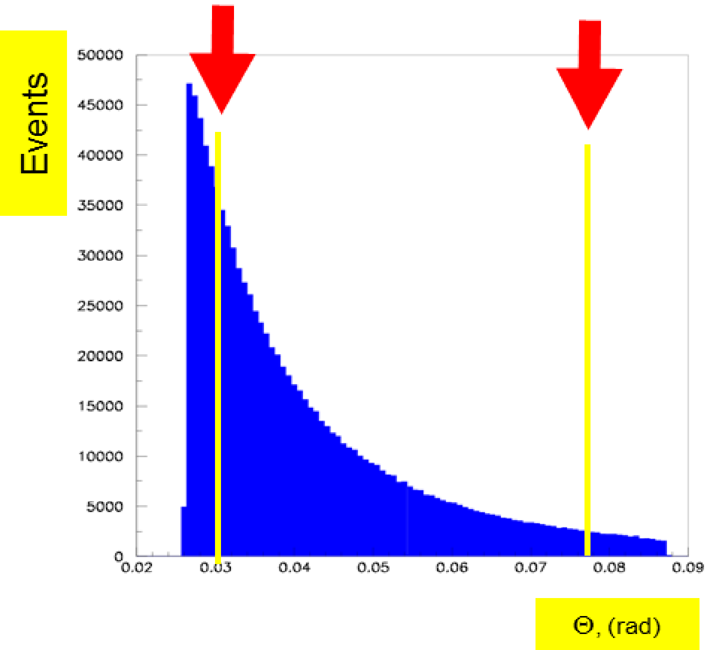
- hermeticity (electron detection at low polar angle)
- beam diagnostics and tuning (fast feedback to machine)

Challenges:
- high precision (LumiCal),
- radiation hardness (BeamCal)
- fast read-out (LumiCal&BeamCal)

Luminosity measurment for e+e- collider
Gauge process used: Bhabha scattering

$e^+e^- \longrightarrow e^+e^- (\gamma)$

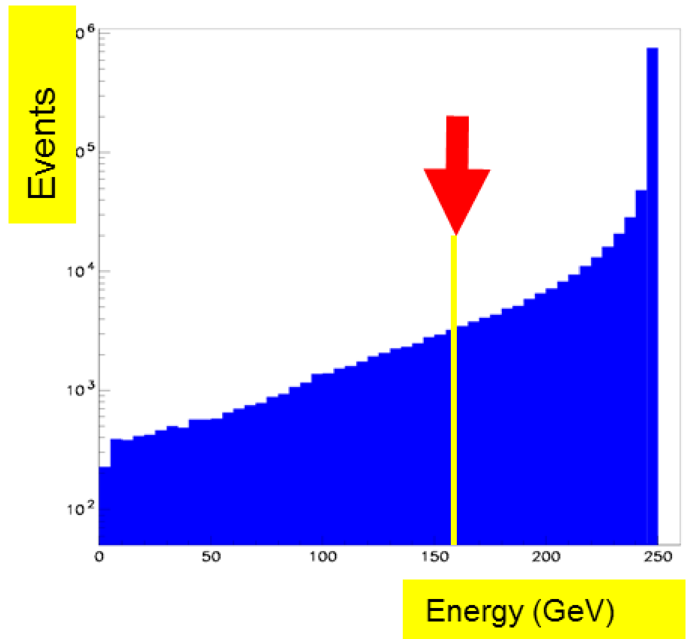
$$\frac{d\sigma_B}{d\theta} = \frac{2\pi\alpha_{em}^2}{s}\frac{\sin\theta}{\sin^4(\theta/2)} \approx \frac{32\pi\alpha_{em}^2}{s}\frac{1}{\theta^3}$$



$L = N / \sigma$

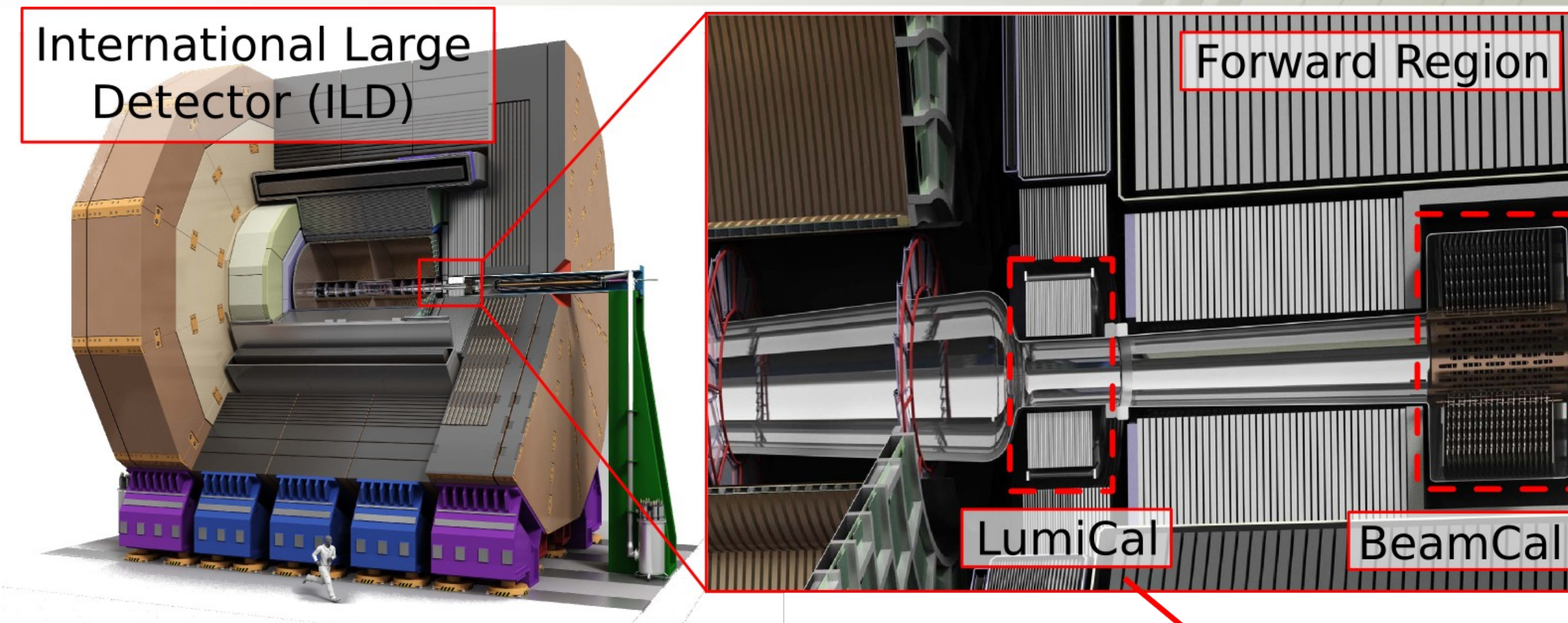
Count Bhabha events

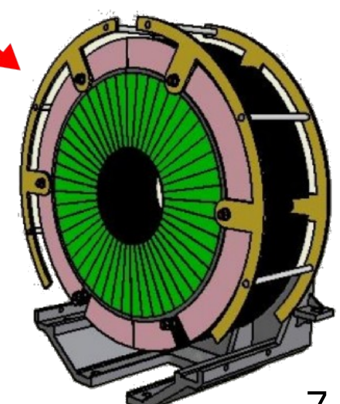
From theory



Required precision:
Inner acceptance radius: < 10 μm
Distance between Calorimeters : ~ 300 μm
Radial beam position : < 500um

LumiCal Detector in ILD
Main contribution of Cracow groups





- **Aim:** Precise measurement of integrated luminosity (based on counting BhaBha events)
- **Implementation :** sampling calorimeter 30 (ILC) / 40 (CLIC) Si/W layers (each W 1 X_0)

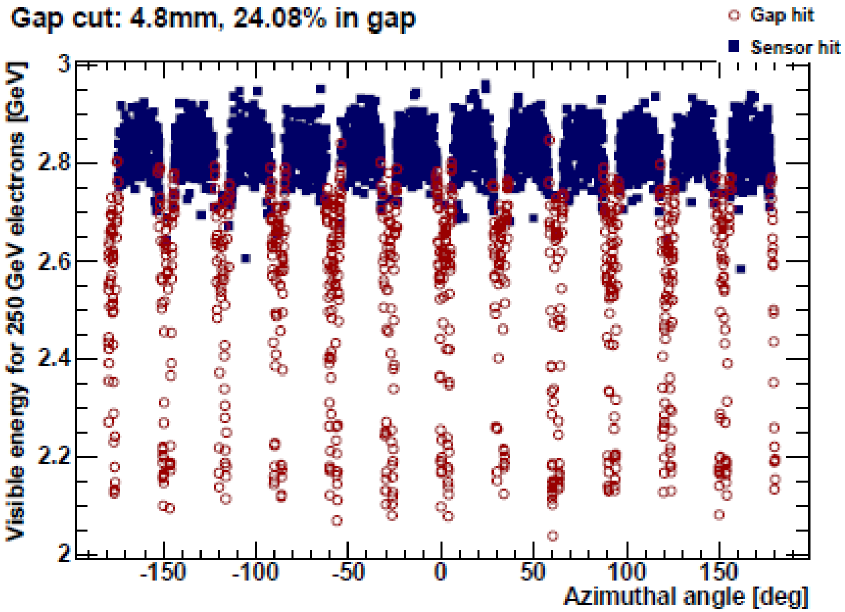
H. Abramowicz et al. , "Forward Instrumentation for ILC Detectors" JINST 5:P12002, 2010

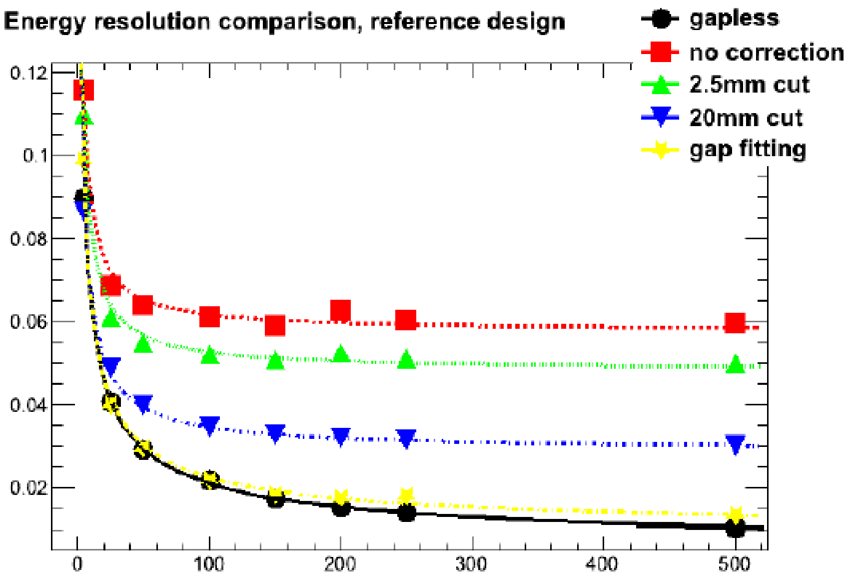
Contributions of Cracow groups in FCAL
Only the main items linked to LumiCal are listed…

- Development of sensors and fanout for LumiCal (IFJ PAN)
- Development of front-end and further readout electronics for LumiCal (AGH-UST)
- Power pulsing/cycling (AGH-UST)
- Construction of LumiCal detector prototype modules (AGH-UST, IFJ PAN)
- Precisely machined tungsten plates (AGH-UST, CERN, IFJ PAN)
- DAQ modules for LumiCal (IFJ PAN, TAU)
- Mechanics for detector prototype and test-beams (CERN, DESY, IFJ PAN)
- Laser alignment system for LumiCal (IFJ PAN)
- Software for LumiCal simulations and its maintenance (IFJ PAN, TAU)
- Test-beam preparations and runs (AGH-UST, DESY, IFJ PAN, TAU)
- Analysis of test-beam data (AGH-UST, DESY, IFJ PAN, TAU)
- **Construction of LumiCal detector prototype (AGH-UST, CERN, DESY, IFJ PAN, TAU) – main goal !**

MonteCarlo studies of LumiCal detector

Example - Effect of dead sensor areas (gaps) on energy resolution



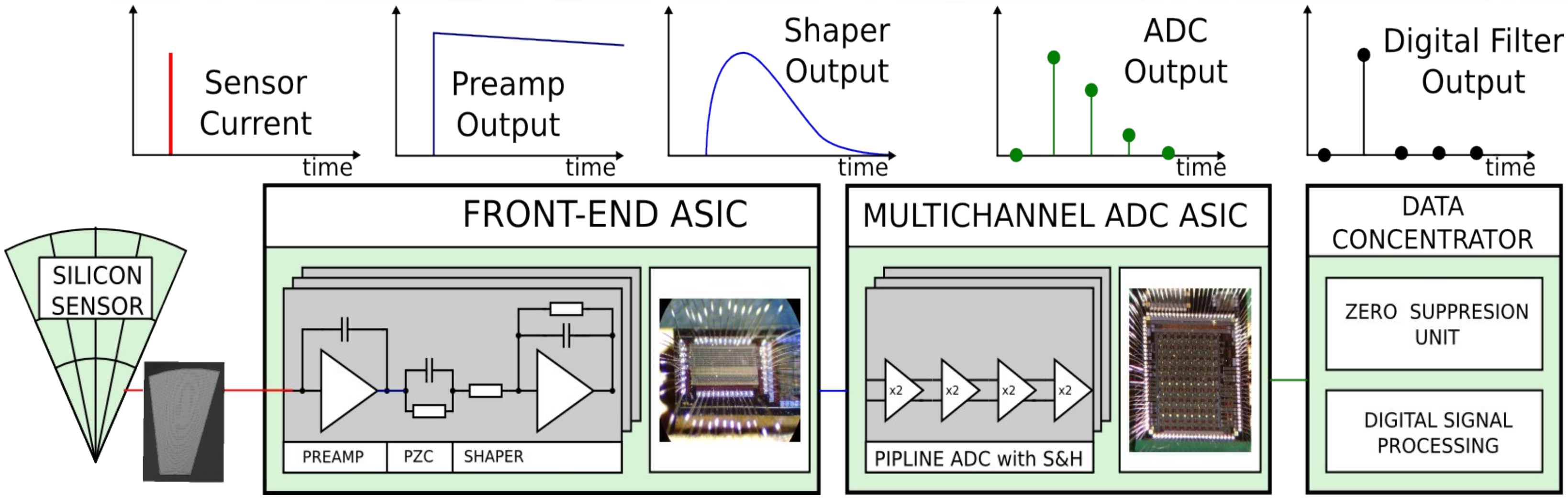


- Visible energy vs azimuthal angle
- In read the events registered in gaps

- Rejecting events from the gaps improves energy resolution but worsens statistics
- Using the correction with dedicated fiting method allows to keep good statistics and good energy resolution

Many other simulations and analyses are performed at IFJ PAN

LumiCal detector readout chain
Developed and built entirely in Cracow

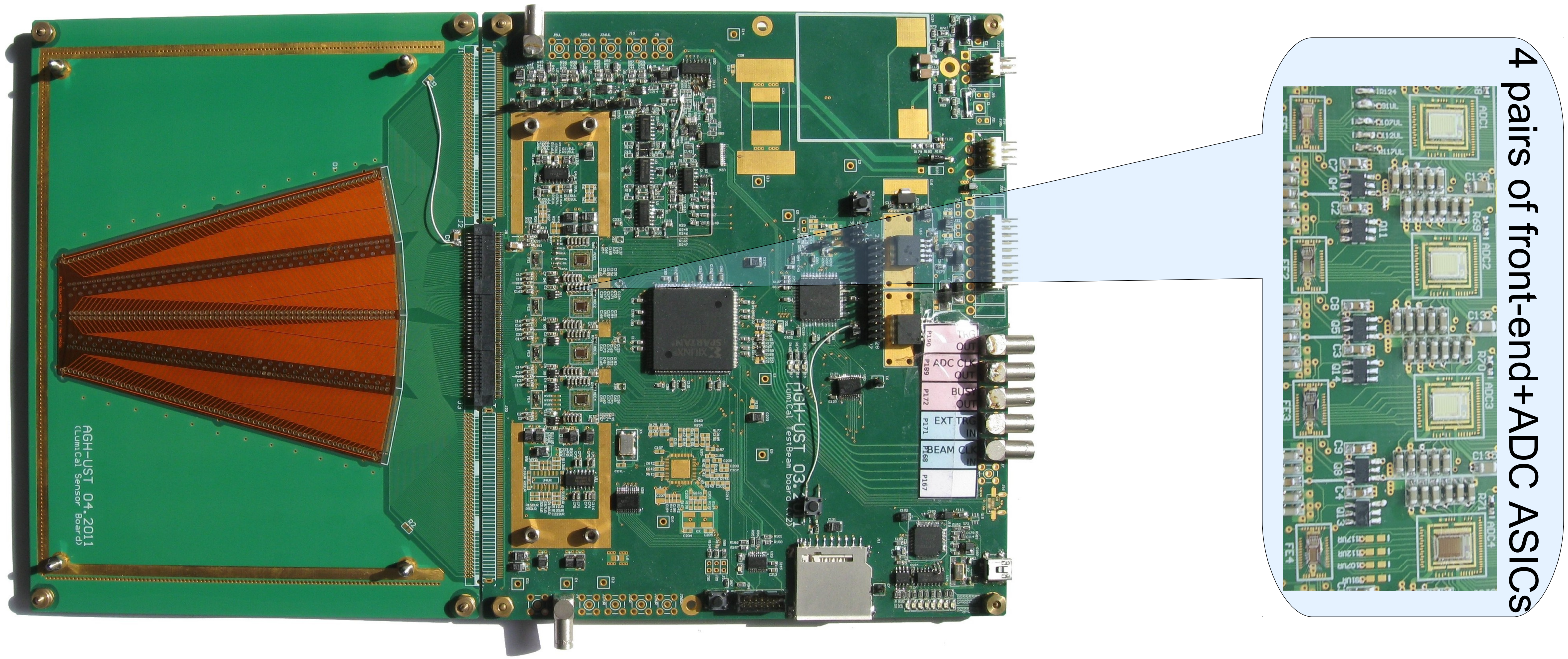


Main components of LumiCal detector prototype:

- 256-pad (64 per sector) silicon sensors (Hammamatsu) and fanout - IFJPAN
- 8 channel front-end ASIC (CMOS AMS 0.35um technology) – AGH-UST
- 8 channel ADC ASIC (CMOS AMS 0.35um technology) – AGH-UST
- FPGA based data concentrator and further readout - AGH-UST

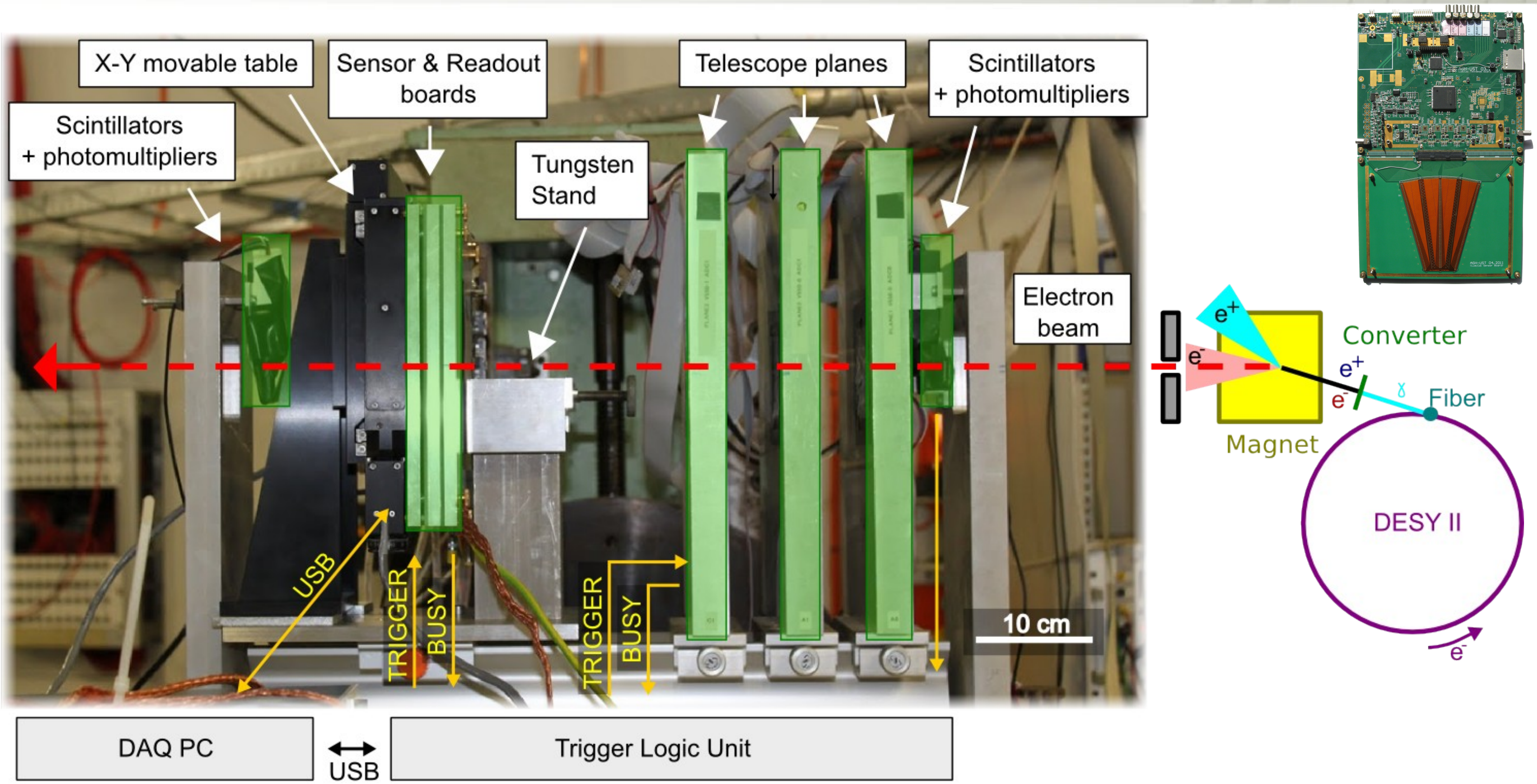
Front-end - M. Idzik, Sz. Kulis, D. Przyborowski, "Development of front-end electronics for the luminosity detector at ILC", NIM A 608 p.169-174, 2009
Multichannel ADC - M. Idzik, K. Swientek, T. Fiutowski, Sz. Kulis, D. Przyborowski "A 10-bit multichannel digitizer ASIC for detectors in particle physics experiments", IEEE Trans. Nucl. Sci. v.59 p.294-302 2012
Data concentration and readout - Sz. Kulis, A. Matoga, M. Idzik, K. Swientek, T. Fiutowski, D. Przyborowski "A general purpose multichannel readout system for radiation detectors", Journal of Instrumentation JINST 7 T01004 2012

LumiCal detector module
Sensor board (IFJ PAN), ASICs&Readout (AGH-UST)



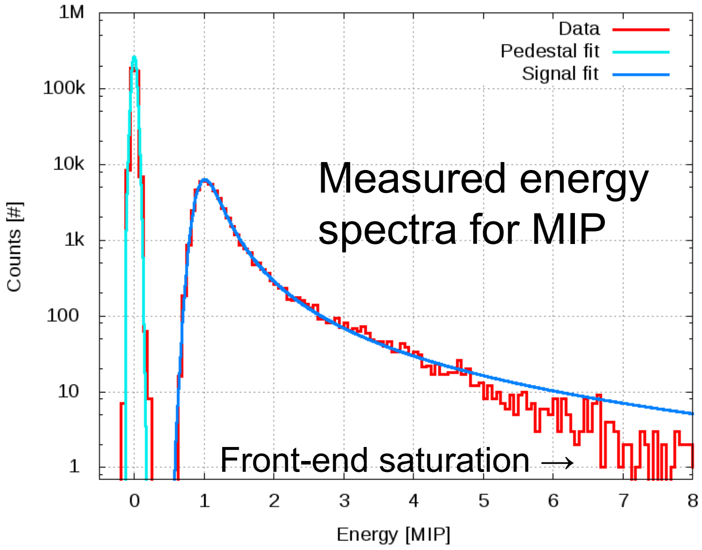
- 32 fully equipped channels (FE+ADC) working with sampling rate up to 20MS/s
- Good performance of detector module verified on 2 testbeams in 2011
- ILC type Power pulsing implemented (1ms_ON/199ms_OFF, ASICs Power_ON/OFF >30)
- Two modules available (Cracow, Zeuthen), with two sensor boards (BeamCal, LumiCal)
- Tests for CLIC are performed with asynchronous readout using deconvolution

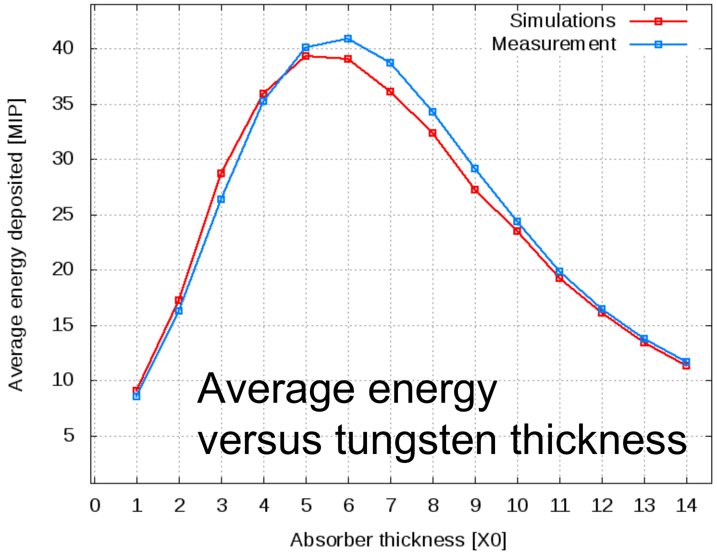
Testbeams of LumiCal and BeamCal in 2011

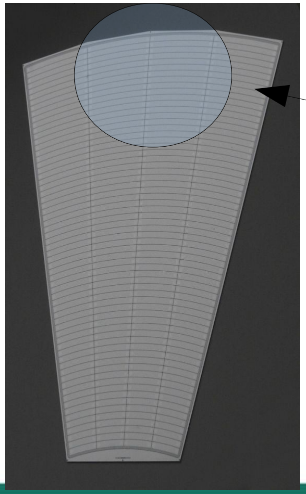


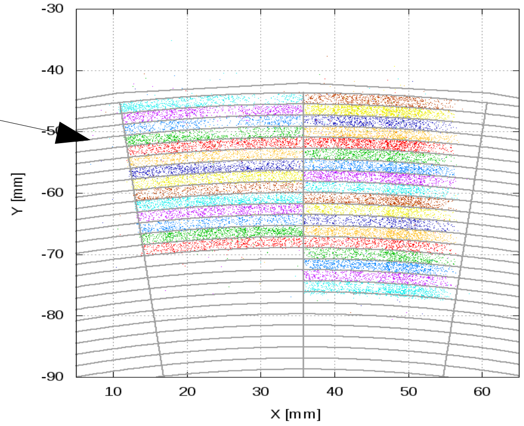
- Two testbeams on 4.5GeV electron beam at DESY performed in 2011
- Operation of LumiCal and BeamCal (with LumiCal readout) detector prototype modules, together with tungsten absorber, verified

Preliminary testbeam results – examples
Energy spectra and position reconstruction









Position reconstructed using the reference data from silicon strip telescope

ILC vs CLIC important issues/challenges

Parameter	ILC	CLIC	
Centre-of-mass energy (GeV)	**500**	**500**	**3000**
Total (Peak 1%) luminosity (10^{34})	2.0(1.5)	2.3(1.4)	5.9(2.0)
Total site length (km)	31	13.0	48.3
Loaded accel. gradient (MV/m)	31.5	80	100
Main linac RF frequency (GHz)	**1.3 (Super Cond.)**	**12 (Normal Conducting)**	
Beam power/beam (MW)	20	4.9	14
Bunch charge (10^9 e+/-)	20	6.8	3.72
Bunch separation (ns)	**330**	**0.5**	
Beam pulse duration (ns)	**1000000**	**177**	**156**
Repetition rate (Hz)	**5**	**50**	
…	…	…	…
Total power consumption (MW)	216	129.4	415

Readout requirements for ILC and CLIC different:

- Synchronous with beam signal measurement feasible at ILC
- Asynchronous amplitude and time measurement needed for CLIC
- Power pulsing feasible for both ILC and CLIC

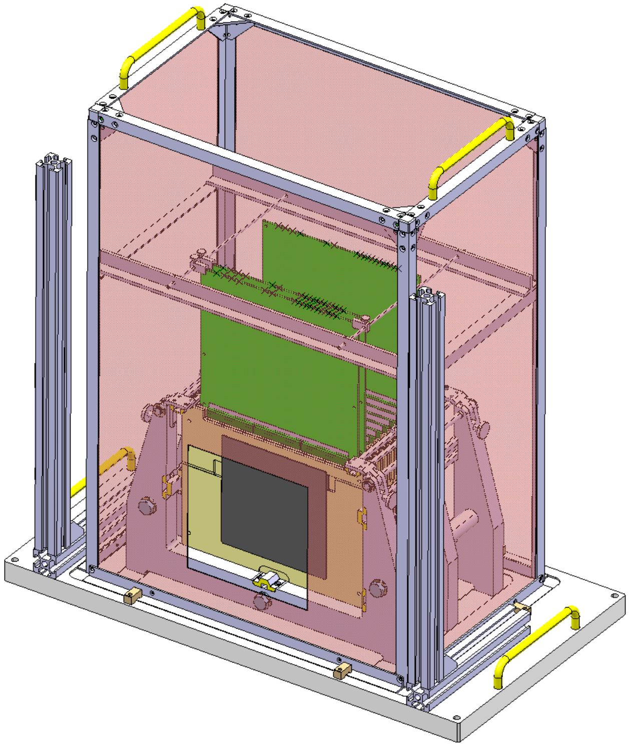
Works on different readout concepts are ongoing...

Sz. Kulis, M. Idzik "Study of readout architectures for triggerless high event rate detectors at CLIC" LCD-Note-2011-015

Plans for next years – AIDA goals

• Build the prototype of LumiCal detector (AGH-UST, CERN, DESY, IFJ PAN, TAU)

- Flexible high precision mechanical structure (CERN)
- Precisely machined tungsten absorber plates (AGH-UST, CERN, IFJ PAN)
- NEW improved version (less power, higher speed, radiation hardness) of LumiCal ASICs in deep submicron 130 nm CMOS, and readout (AGH-UST)
- Fully assembled sensor planes covering 30^{o} (AGH-UST, DESY, IFJ-PAN, TAU)
- Position control devices (IFJ-PAN)
- Power pulsing (AGH-UST)
- Data acquisition (IFJ-PAN, TAU)

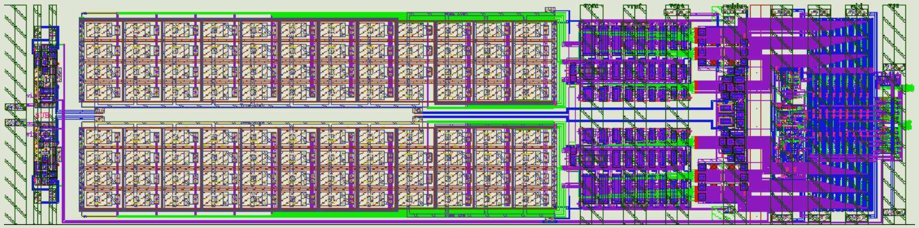


Works on LumiCal prototype already started...

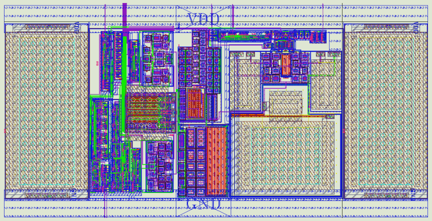
Mechanical structure

CERN

Layouts of ASICs prototypes in IBM 130nm CMOS



10-bit ADC
600um x 145um



PLL
310um x 150um

AGH-UST (submitted in Feb. 2012)

Precisely machined first 10 Tungsten plates are arriving (AGH-UST, CERN, IFJ PAN)
Other works are ongoing...

Detector R&D for LHCb upgrade

- Institutions in Poland:
  - **Kraków: AGH-UST**
- Participants:
  - **Staff/PhD 2/2 just starting, should/will increase**
- Main responsibilities
  - **Readout for tracking detectors**
- Main contributions and financing:
  - **Activity started few months ago**
  - **Small contrib. with local resources ~25kE**
  - **Funding request will be done soon**
  - **Estimated cost ~1M Euro**

Member of the LHCb Upgrade Resource Board

LHCb upgrade
Towards discovery experiment

Why upgrade ? Is there something wrong with present design ?

- Superb performance – but present 1 MEvent/s readout is a sever limit:
  - can collect ~ 1.2 fb^{-1} per year, ~ 5 fb^{-1} for the „phase 1" of the experiment
  - cannot gain with increased luminosity – trigger yield for hadronic events saturates
- Upgrade plans for LHCb do not depend on the LHC machine
  - we use presently only small fraction (~3 10^{32}) of the luminosity
- Move to fully software trigger (now L0 hardware)
  - full rate event read-out 40 MEvent/s (40 times gain !!!)
- HLT output 20 kEvents/s (now ~3.5k) , more than 50 fb^{-1} data for „phase 2"
  - can gain factor 2 in signal rate for hadronic events
  - expand physics scope to: lepton flavor sector, electroweak physics, exotic searches

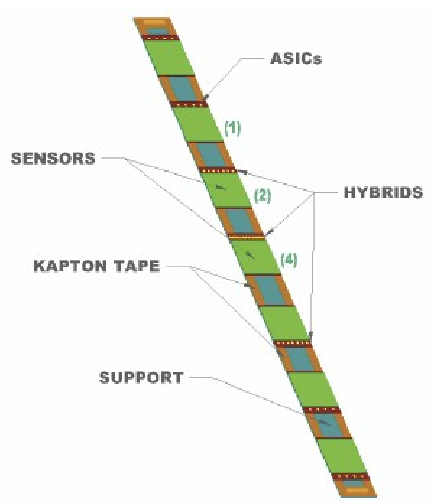
What are the key changes needed:

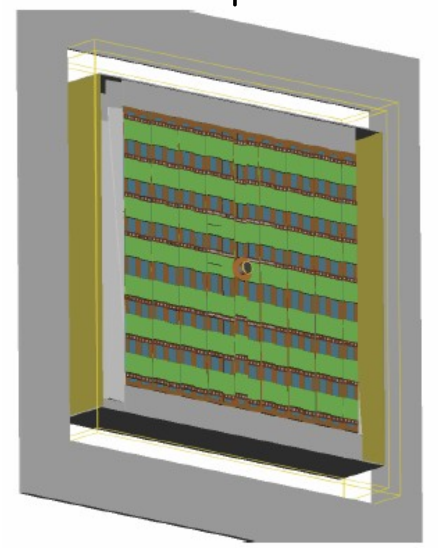
- new faster readout electronics
- redesign DAQ system

Subdetectors upgrade – Intermediate tracker TT, VELO-Vertex Locator, Main tracker...

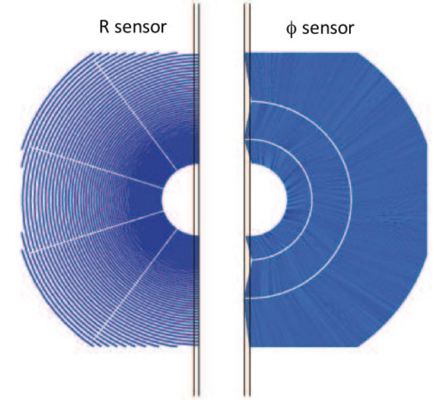
Intermediate tracker TT:

- Selection of high momentum tracks
- Reconstruct trajectories of long-lived tracks
- Track segment to ease pattern recognition
- Reconstruction of momentum of slow particles





Strip option for VELO Vertex Locator



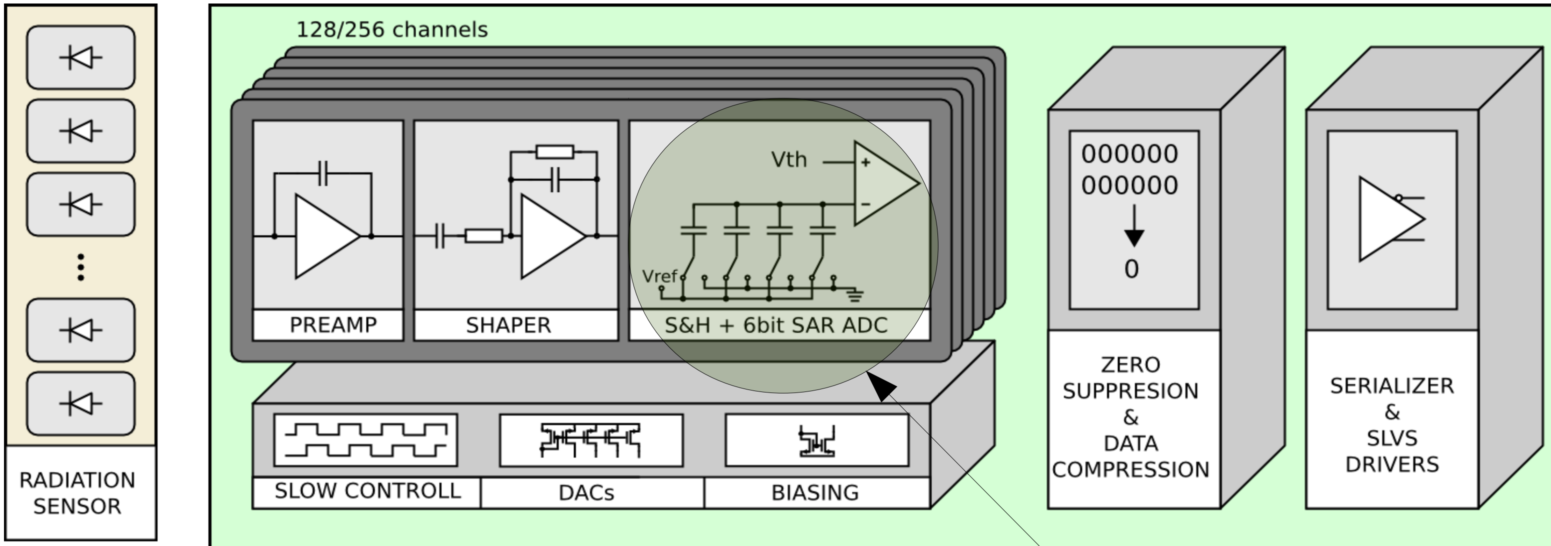
Two options for Inner tracker IT (part of main tracker):

- Silicon strip tracker
- Scinitilllating fiber tracker

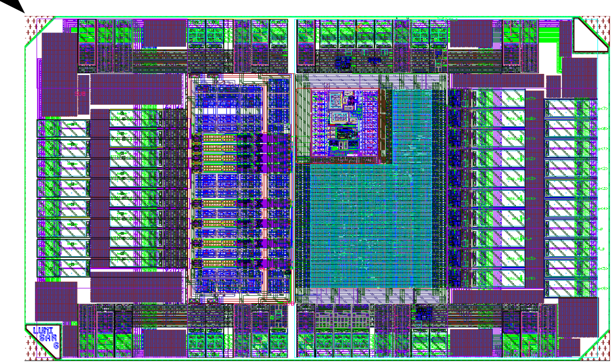
AGH-UST group is taking responsibility for:

- Read-out electronics for: Intermediate tracker TT, strip VELO option, contribution to IT tracker under discussions
- Firmware and new DAQ for VELO

Readout for LHCb tracking detectors
Key element – multichannel ASIC with complex signal processing



6-bit ADC submitted May 2012



- Complex 128/256 channel ASIC
  - Preamplifier, shaper ADC, zero supp., serializ.
- CMOS 130nm technology
- Application in various detectors
  - TT tracker, VELO strip, IT tracker ?

Summary

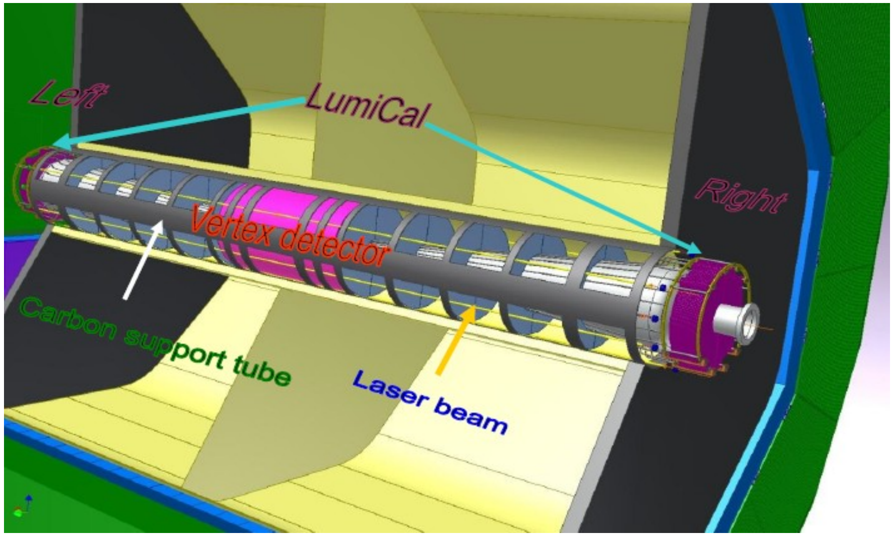
- Linear colliders R&D
  - Polish groups are strongly involved in Forward Calorimetry for future LC and are leading contributors in the LumiCal detector R&D. This was possible thanks to participation in European projects: EUDET (FP6), MC-PAD, AIDA (FP7), together with the Polish contribution.
  - R&D projects on detectors involving advanced technologies are very costly, comparable to the construction cost, while there is no dedicated path of funding for such projects, like it is for the approved experiments.
  - Therefore, a) a long term future is NOT clear, b) present Polish contribution, both in people and funds, is very limited
- LHCb and general detector R&D
  - Readout for tracking detectors in LHCb upgrade may be one of the major contributions of Polish groups into LHC upgrade
  - Application of modern deep submicron CMOS technologies in future detectors of HEP experiments is one of the major Polish R&D fields (ILC/CLIC, LHCb, ATLAS, ...)

Thank you for your attention

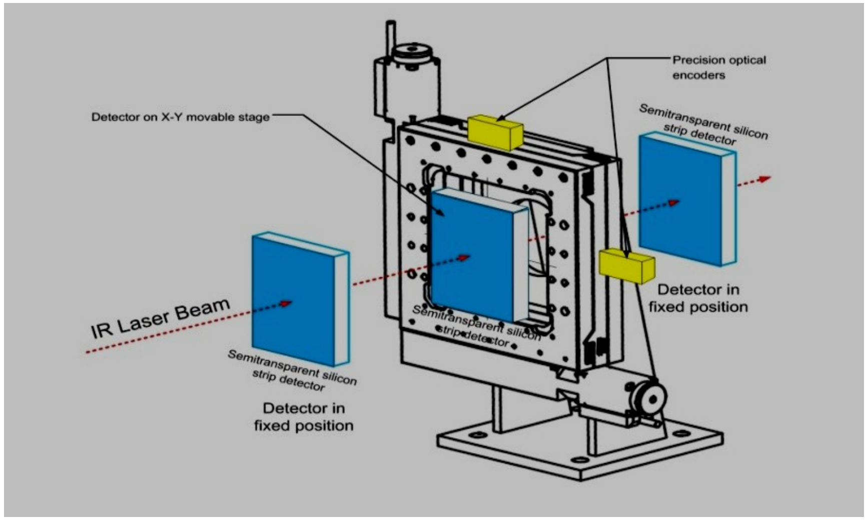
Laser positioning system (LAS)

The laser positioning system will contain the main components:
- infra-red laser beam and transparent silicon position sensors
- tuneable laser(s) working within Frequency Scanning Interferometry (FSI) system

Laser beam for LumiCal calorimeter alignement



Laser positioning using semitransparent sensors

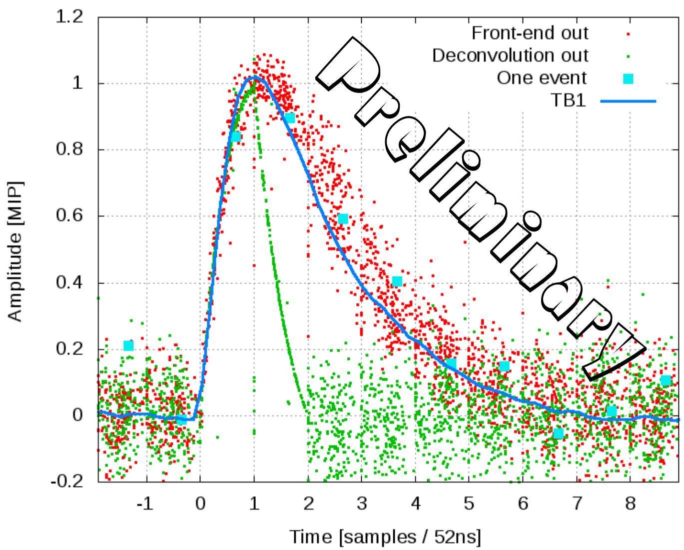


CLIC detector challenge – detection of high rate asynchronous (triggerless) events

How to read several events within 156ns beam train period ?
Reconstructing not only amplitude but also TIMING info!

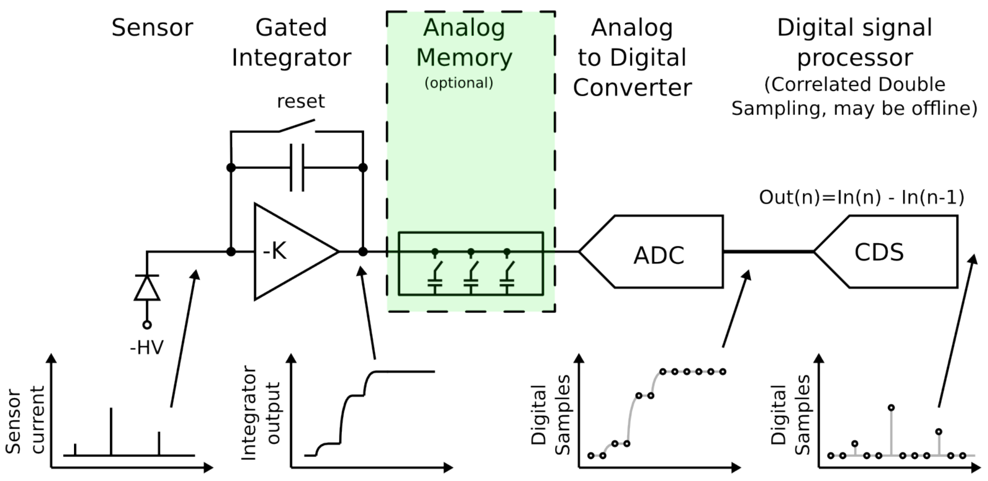
Deconvolution method – type of digital filtering

- To shorten the pulse length use weighted sum of signal samples
- CR-RC shaping needs only 3 samples to be summed
- Very fast sampling ~50-100 MS/s



Gated integrator & Correlated double sampling (CDS)

- Reset before the beam train
- Integration during the beam train
- Very fast sampling ~50-100 MS/s



Both methodes are under study...

Sz. Kulis, M. Idzik "Study of readout architectures for triggerless high event rate detectors at CLIC" LCD-Note-2011-015